Part Three. Power Generation

CHAPTER 8

Generators

The demands for electricity in military field operations are numerous and varied. Electricity powers equipment ranging from rock crushers to missile launchers. It services aircraft, ships, and land vehicles. Electricity is required for command and control operations, medical support, and other facilities. The Department of Defense (DOD) uses a *family* of generator sets to produce the electrical power needed by military field units. This family was developed in the 1960s to reduce the variety of generator sets and repair parts required by all services. This chapter describes the generators in this family and provides instructions for their use.

Section I. Mobile Generator Sets and Electric Distribution Systems

MOBILE GENERATOR SETS

A mobile electric generator set converts mechanical energy to electrical energy by using an engine to drive the generator. An internal fuel supply makes the set independent and mobile. When equipped with accessories such as an electric distribution system, this set produces all the power needed by military forces in the field. The elements of an electrical power-generating site in the field are shown in *Figure 8-1, page 8-2*.

Table 8-1, page 8-3, lists the characteristics of generator models found in the DOD inventory and shows kilowatts, frequency rating (in cycles per second), and voltage output. The rated current of DC generators is shown in the output column. The characteristics in the table must match the requirements for the equipment that is being connected to the generator set.

Table 8-2, page 8-4, shows the generator models separated by the type of engine that drives the generator, the application (use) for each model, and the TM that provides additional information about it.

Electric generator sets are driven by gasoline or diesel engines and produce AC or DC. AC changes in value and reverses its direction of flow at regular intervals; DC is constant in value and flows in only one direction.

AC GENERATOR SETS

The lighting and power loads of most field units require voltages and frequencies supplied by AC systems. While 60-cycle AC is used much of the time, loads with specific voltage, frequency, and power requirements may use up to 400-cycle AC. Radar, fire-control sets, communication controls, and guided-missile systems are examples of equipment that require 400-cycle AC. Some equipment can operate with either 60- or 400-cycle AC.

AC generator sets are designed to operate at various voltages, frequencies, and power levels. To meet a particular power demand, an operator must choose a set with the proper characteristics. If a large set is needed but is unavailable, several small sets, each located near the load to be supplied, may be used. Additional operators and maintenance personnel may be required if several small sets replace a large one.

Mobility is a factor in selecting generator sets for field use. Sets that produce 60 kilowatts of electricity are often used in the field because they can be transported in 2 1/2-ton trucks. Sets that produce more than 60 kilowatts of power must be transported in 5-ton trucks. Therefore, a field unit may make parallel connections between several 60-kilowatt generator sets to produce an amount of power equivalent to one large set.

Small

Small AC generator sets are driven by gasoline engines and produce 0.5 or 1.5 kilowatts of electricity. The output is delivered in 120 or 240 volts, with a single-phase distribution system, at a frequency of 60 cycles. Sets that produce 0.5 kilowatts are available at a frequency of 400 cycles; sets that produce 1.5 kilowatts are available at a frequency of 60 cycles.

The 1.5-kilowatt, 60-cycle generators are the most versatile and widely used small sets in the DOD inventory. They satisfy the communications and lighting needs of small field units.

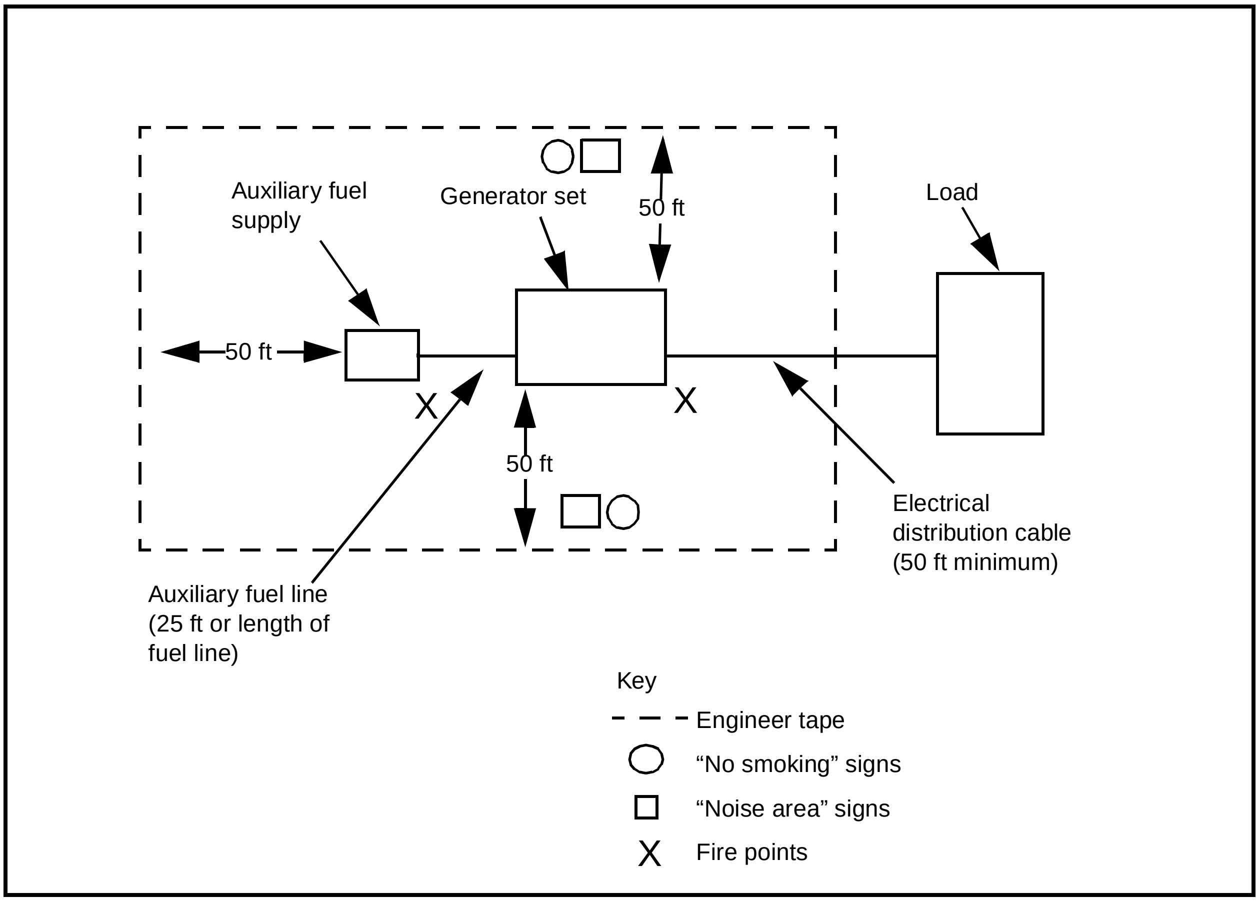

Figure 8-1. Typical electrical power-generating site

Table 8-1. Generator set characteristics

Model	Kilowatts	Frequency (Cycles per Second)	Voltage Output
MEP-014A	0.5	60	120/240 V, single-phase, three-wire
MEP-024A	0.5	DC	28 V, 17 amps
MEP-019A	0.5	400	120/240 V, single-phase, three-wire
MEP-015A	1.5	60	120/240 V, single-phase, three-wire
MEP-025A	1.5	DC	28 V, 53 amps
MEP-016A	3	60	120 V, three-phase 120/240 V or 120/208 V, three-phase, four-wire
MEP-021A	3	400	120 V, three-phase 120/240 V or 120/208 V, three-phase, four-wire
MEP-026A	3	DC	28 V, 103 amps
MEP-002A	5	60	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-017A	5	60	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-022A	5	400	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-018A	10	60	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-023A	10	400	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-003A	5	60	120 V, three-phase, three-wire 120/240 V or 120/208 V , three-phase, four-wire
MEP-112A	10	400	120 V, three-phase, three-wire 120/240 V or 120/208 V, three-phase, four-wire
MEP-004A	15	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-103A	15	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-113A	15	400	120/208 V or 240/416 V, three-phase, four-wire
MEP-005A	30	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-104A	30	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-114A	30	400	120/208 V or 240/416 V, three-phase, four-wire
MEP-006A	60	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-105A	60	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-115A	60	400	120/208 V or 240/416 V, three-phase, four-wire
MEP-404B	60	400	120/208 V or 240/416 V, three-phase, four-wire
MEP-007A	100	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-007B	100	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-106A	100	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-116A	100	400	120/208 V or 240/416 V, three-phase, four-wire
MEP-009A	200	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-108A	200	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-029A	500	50/60	120/208 V or 240/416 V, three-phase, four-wire
MEP-029AHK	500	50/60	120/120 V or 120/208 V, three-phase, four-wire

Table 8-2. Mobile electric generator sets

Model	Kilowatts	Application	Voltage	Technical Manual
Gasoline-Engine Driven				
MEP-014A	0.5	Utility	AC	TM 5-6115-329-14
MEP-019A	0.5	Utility	AC	TM 5-6115-329-14
MEP-024A	0.5	Utility	DC	TM 5-6115-329-14
MEP-015A	1.5	Utility	AC	TM 5-6115-323-14
MEP-025A	1.5	Utility	DC	TM 5-6115-323-14
MEP-016A	3	Utility	AC	TM 5-6115-271-14
MEP-021A	3	Utility	AC	TM 5-6115-271-14
MEP-026A	3	Utility	DC	TM 5-6115-271-14
MEP-017A	5	Utility	AC	TM 5-6115-332-14
MEP-022A	5	Utility	AC	TM 5-6115-332-14
MEP-018A	10	Utility	AC	TM 5-6115-275-14
MEP-023A	10	Utility	AC	TM 5-6115-275-14
Diesel-Engine Driven				
MEP-002A	5	Utility	AC	TM 5-6115-584-12
MEP-003A	10	Utility	AC	TM 5-6115-585-12
MEP-112A	10	Utility	AC	TM 5-6115-585-12
MEP-005A	30	Utility	AC	TM 5-6115-465-12
MEP-104A	30	Precise	AC	TM 5-6115-465-12
MEP-114A	30	Precise	AC	TM 5-6115-465-12
MEP-006A	60	Utility	AC	TM 5-6115-545-12
MEP-105A	60	Precise	AC	TM 5-6115-545-12
MEP-115A	60	Precise	AC	TM 5-6115-545-12
MEP-007A	100	Utility	AC	TM 5-6115-457-12
MEP-007B	100	Precise	AC	TM 5-6115-457-12
MEP-106A	100	Precise	AC	TM 5-6115-457-12
MEP-116A	100	Precise	AC	TM 5-6115-457-12
MEP-009A	200	Utility	AC	TM 5-6115-458-12
MEP-108A	200	Precise	AC	TM 5-6115-458-12
MEP-029A	500	Utility	AC	TM 5-6115-593-12
MEP-029AHK	500	(with options)	AC	TM 5-6115-593-12
Turbine-Engine Driven				
MEP-404B	60	Precise	AC	TM 5-6115-603-12

Medium

Medium AC generator sets are driven by gasoline or diesel engines and produce between 3 and 10 kilowatts of electricity. These generator sets can deliver 60- or 400-cycle AC. A reconnection switch enables the operator to connect any of the following distribution systems at the rated kilowatt output:

- Single-phase, two-wire, 120 volts.
- Single-phase, two-wire, 240 volts.
- Three-phase, three-wire, 120 volts.
- Three-phase, four-wire, 210/208 volts.

Generator sets that produce 60-cycle AC are used for general power requirements because they are versatile and their power output ranges considerably. Sets that produce 10 kilowatts at 60 cycles are the most versatile because their output is adequate for small maintenance shops and other relatively large loads. These generators are usually mounted on skids to increase mobility.

Large

Large AC generators are driven by diesel engines and produce between 15 and 500 kilowatts of electricity. These generators can deliver 50/60- or 400-cycle AC. They can deliver three-phase, four-wire power at 120/208 or 240/416 volts. An output delivered at 50 cycles is 82 percent of the rated power; an output delivered at 60 cycles is 100 percent of the rated power.

Large generator sets produce electricity for lighting and power in buildings and other general loads. They can produce enough output to supply several kinds of loads simultaneously over a relatively wide area. Standard-frequency generator sets are rated at 50/60 cycles; high-frequency generator sets are rated at 400 cycles.

DC GENERATOR SETS

DC generator sets provide power for specific pieces of equipment. For example, they are used to charge batteries, operate communications equipment, and provide power to some missile equipment. Thus, the need for DC generator sets in the field is less than the need for AC generator sets. The three DC generator sets listed in *Tables 8-1 and 8-2, pages 8-3 and 8-4*, are basic AC generators that use rectifiers to convert the AC voltage to DC voltage.

DATA PLATES

Three data plates located on the generator provide pertinent information about output, capabilities, and performance characteristics. Refer to the description and data section in the appropriate TM for information about a specific generator that is not on the plates.

- Alternator Data Plate. Specifies the alternator ratings for 50-, 60-, and 400-cycle outputs. It provides the serial number, kilowatt rating, DC excitation requirement, date of manufacture, voltage and ampere outputs, power factors, model number, and revolutions per minute (rpm). On most models, this plate is attached to the main generator housing.
- Equipment Identification Plate. Specifies the model number, serial number, horsepower rating, date of manufacture, number and firing order of cylinders, national stock number, contract number, and occasionally, the applicable TM. A typical equipment identification plate is shown in *Figure 8-2*.

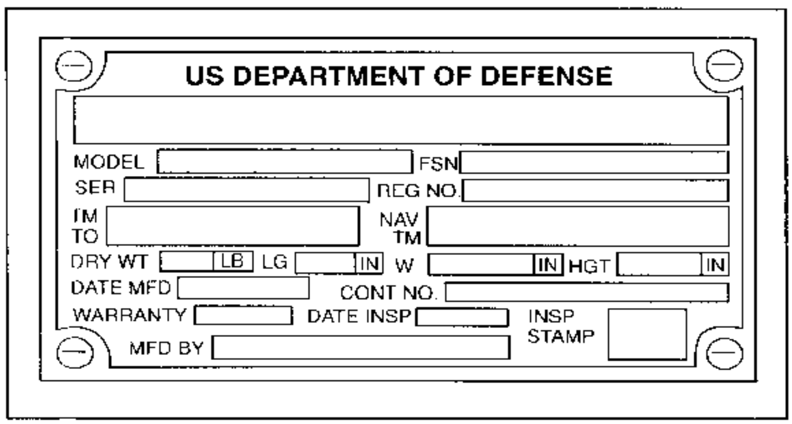

Figure 8-2. Typical equipment identification plate

- Starting and Stopping Instruction Plate. Specifies starting and stopping and/or paralleling and synchronizing procedures and is frequently called the *paralleling and synchronizing instruction plate*. It may also show preliminary positioning of controls and procedures for using the dark-lamp method of synchronizing and paralleling generators. This plate is located inside the main control-panel cover.

ELECTRIC DISTRIBUTION SYSTEMS

A distribution system transfers electricity from its source in the generator to loads such as heaters, motors, or lights. The system is identified by the number of phases, number of wires, and voltages between wires. Operators must check the data plates on the equipment before connecting a distribution system to the load.

Distribution systems are classified according to the voltage used to carry the power from the power source to the distribution transformers or to the loads.

WARNING

Any attempt to operate equipment at other than its rated frequency will damage it.

Military field units commonly use one of four systems:

SINGLE-PHASE, TWO-WIRE

A single-phase, two-wire distribution system (*Figure 8-3*) has one of the two wires from the generator set connected to the neutral wire. The neutral wire is called the *grounded wire* or the *grounded circuit conductor*. The second wire, called the *live wire* or *ungrounded conductor*, is connected to the load. Usually, there is a difference of 120 volts between these two wires. Any single-phase, two-wire, 120-volt load can be connected to both the live wire and the grounded wire. This system supplies electricity for light bulbs, portable tools, and most equipment requiring low power.

SINGLE-PHASE, THREE-WIRE

A single-phase, three-wire distribution system (*Figure 8-4*) has one grounded wire and two live wires. It is called a single-phase system because there is no phase difference between the two available voltages. The difference in voltage between either of the two live wires and the grounded wire is usually 120 volts. The difference in voltage between the two live wires is 240 volts. This system supplies power directly to small loads such as lighting in barracks.

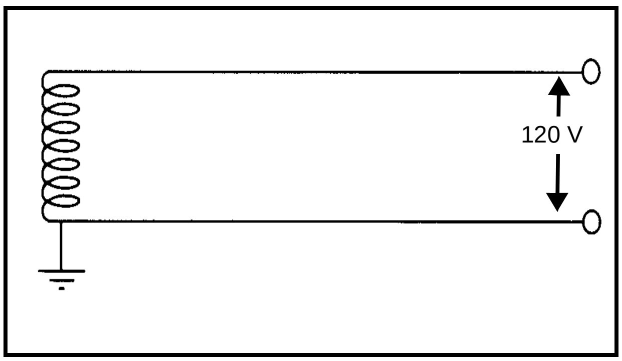

Figure 8-3. Single-phase, two-wire distribution system

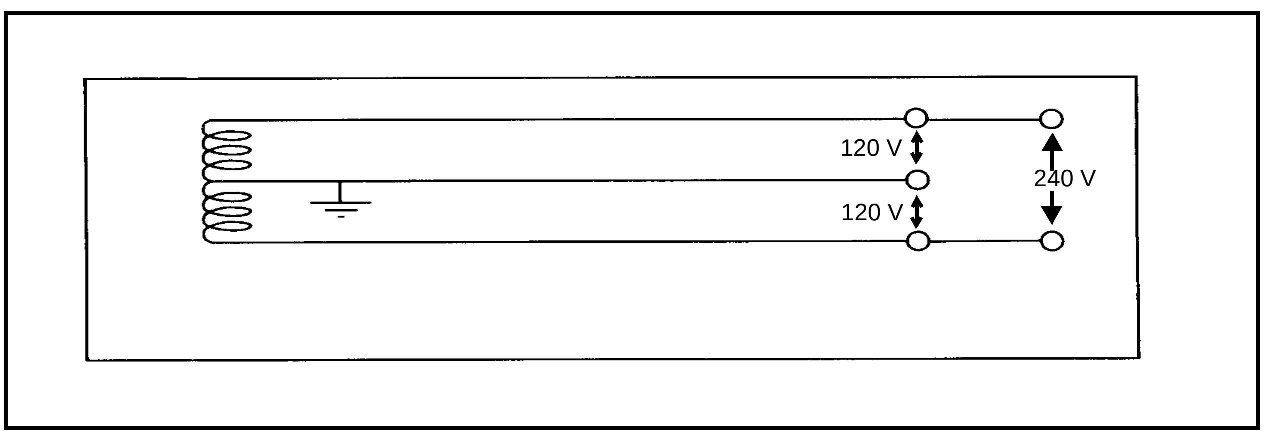

Figure 8-4. Single-phase, three-wire distribution system

THREE-PHASE, THREE-WIRE

All three wires in a three-phase, three-wire distribution system (*Figure 8-5*) are live wires. Thus, a three-phase, three-wire, 120-volt load can be connected to all three wires. This system requires a generator set designed to produce three-phase voltage. Because only one magnitude of voltage is available from this kind of generator, the loads must require the same voltage. This system supplies power to loads in structures where the three-phase power load is larger than the single-phase lighting load. The single-phase lighting load in such a structure is supplied from a separate single-phase service or by a step-down transformer.

THREE-PHASE, FOUR-WIRE

A three-phase, four-wire distribution system (*Figure 8-6, page 8-8*) may be designed to produce single-phase or three-phase voltages. For example, the generator could produce 120 and 208 volts or 240 and 416 volts. A 240/416 voltage connection is common on generator sets that produce from 15 to 500 kilowatts of electricity. This system, which is more flexible than the single-phase systems, supplies power to structures that require substantial amounts of power and lighting, such as shops and hospitals.

Generator sets are designed so that the ratio of the higher (line) voltage to the lower (phase) voltage is always the same and cannot be changed (1.73 times the phase voltage equals the line voltage). Thus, any—

- Single-phase, two-wire, 120-volt load can be fed power by making a connection between any live wire and the grounded wire.
- Single-phase, two-wire, 208-volt load can be fed between any two live wires.
- Single-phase, three-wire, 120/208-volt load can be fed by making a connection to two live wires and the grounded wire.
- Three-phase, three-wire, 240-volt load can be fed by repositioning the tap change board and the connection to the three live wires.
- Three-phase, four-wire, 120/208-volt load can be fed power by making a connection to all four wires.

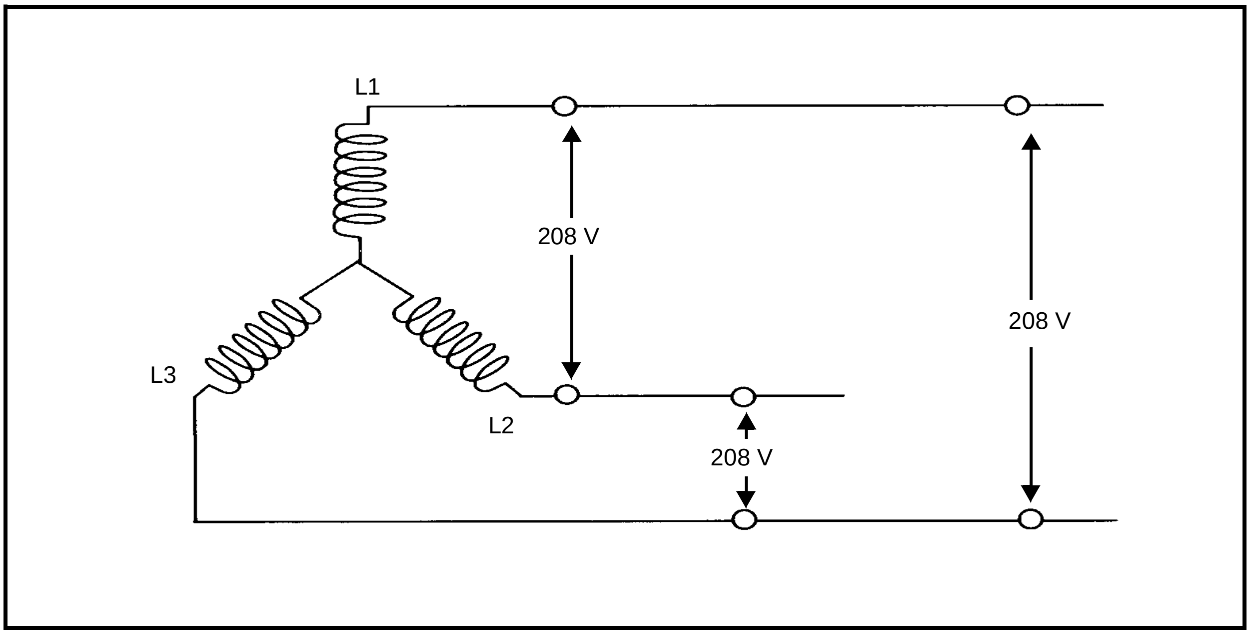

Figure 8-5. Three-phase, three-wire distribution system

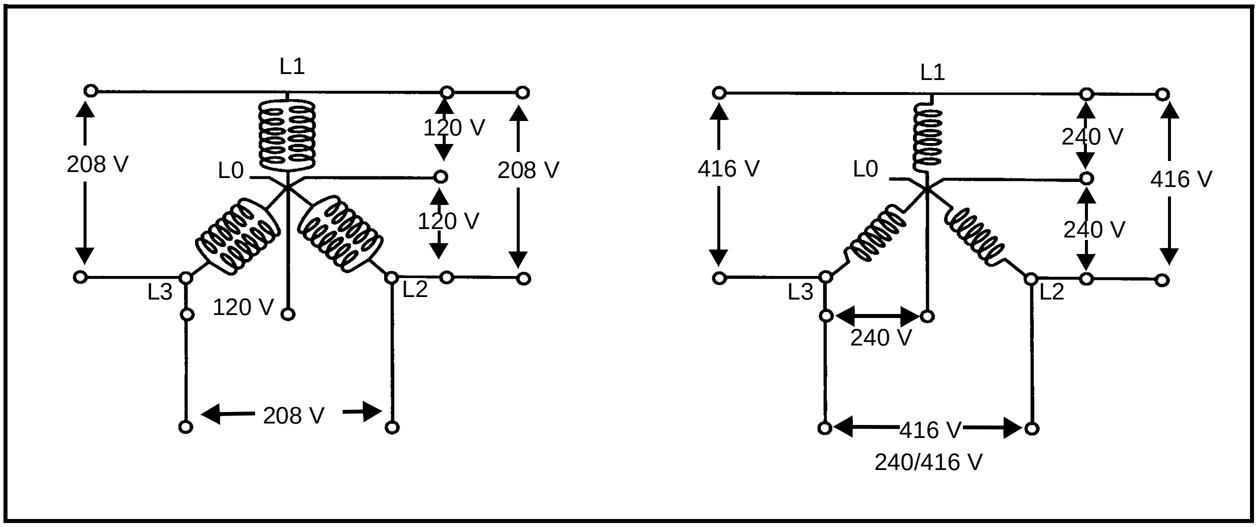

Figure 8-6. Three-phase, four-wire distribution system

Section II. Generator Selection and Operation Principles

SELECTING THE GENERATOR

Selecting generators that can produce the power required by a field unit is an important function. The operator or person responsible for this function must select the number and types of generators that can best meet the unit's needs. Preliminary tasks that must be completed before selecting power-generating equipment are computing the load, computing the cable size, and balancing the load required for the field unit.

COMPUTING THE LOAD

You need an accurate estimate of the load requirement before you can properly design a field unit's power distribution system. The estimated load is determined from the size and location of the load. Complete the following steps to determine the field unit's load requirement:

Step 1. Map the field unit. Locate all structures that require electrical power and mark them on a map. Identify each structure as shown in *Figure 8-7*.

Step 2. Determine the electrical load for each area. Electrical loads are usually measured in amperes, kilowatts, or kilovolt-amperes. The total electrical load fluctuates constantly as equipment starts and stops.

Step 3. Compute the connected load for each structure. The connected load, computed from the electrical load and usually measured in kilowatt-amperes, should total the wattage required for all lights and electrical devices plus the total horsepower of all motors.

Step 4. Compute the demand load. The demand load, computed from the connected load, is the maximum demand required to serve a connected load. The demand load is usually less than the connected load because all equipment in a building seldom operates at one time. The ratio between the estimated maximum demand load and the connected load is the demand factor. Note that the demand load is never greater than the connected load, but the demand and connected loads may be the same if the mission of a tactical shop requires that all electrical equipment be operated simultaneously. The demand factors established for the design of several types of military structures are

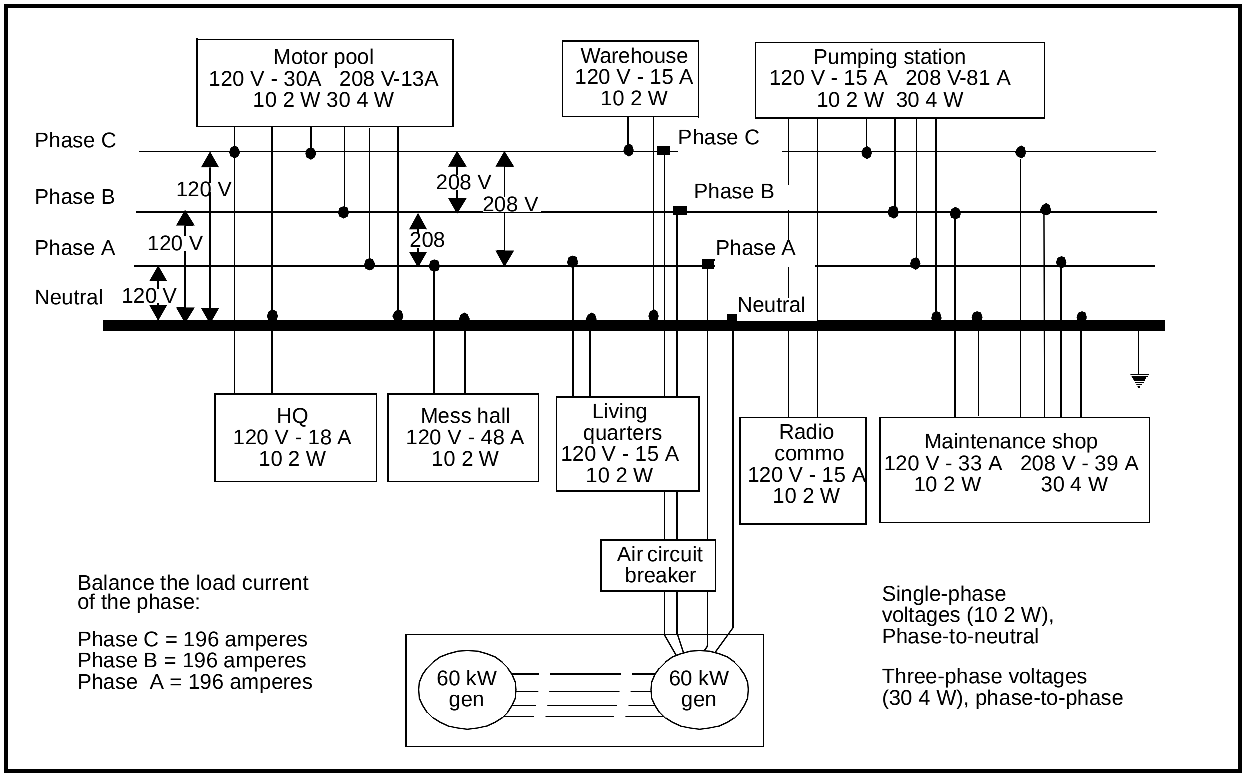

Figure 8-7. Load requirements of a military field installation

listed in *Table 8-3*. Use the following formula to determine the demand load when you know the demand factor:

Demand load = connected load x demand factor

Table 8-3. Demand factors

Structure	Demand Factor
Housing	9
Aircraft maintenance facilities	7
Operation facilities	8
Administrative facilities	8
Shops	7
Warehouses	5
Medical facilities	8
Theaters	5
Navigational aids	7
Laundry, ice plants, and bakeries	10
All others	9

Step 5. Compute the diversity factor. Measured at the point of supply, the diversity factor is the ratio of the sum of the maximum power demands for the component parts of a system to the maximum demand of the entire system. The diversity factor is similar to the demand factor except that it deals with the actual demand load rather than the potential demand load. For example, a generator set may serve three demand sites, each with a maximum demand of 30 kilowatts, as shown in *Figure 8-8, page 8-10*. In this example, the potential demand load is 90 kilowatts. Because maximum demands at the three sites do not occur simultaneously, the maximum demand load on the generator set is only 60 kilowatts, not 90 kilowatts.

Demand and diversity factors are used to plan the design of electrical facilities and determine the type and size of generator sets required for a field unit. Demand factors are also used to rearrange existing facilities. For example, additional equipment may greatly increase the connected load of a structure, but it may or may not require a change to the serving generator set.

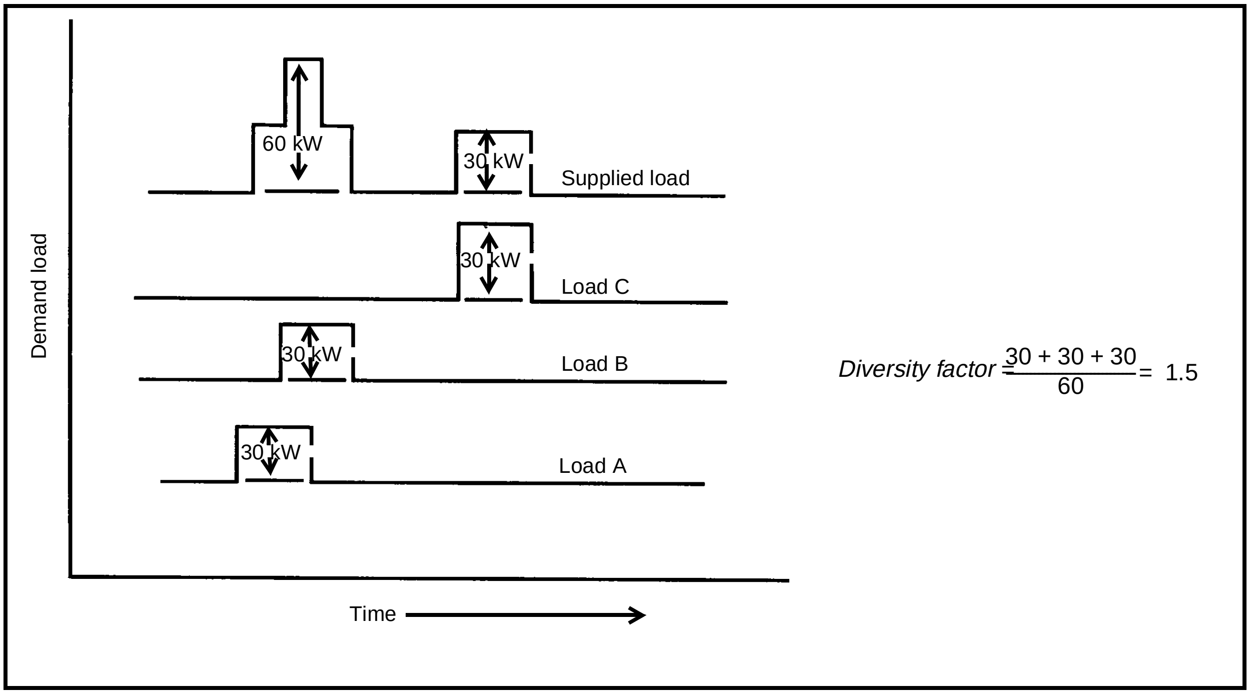

Figure 8-8. Diversity factor

Diversity factors of significant loads must be considered when they contribute to peak loads. Loads that occur during peak times may affect the capacity required for a generator set, while loads that occur during nonpeak times may not. For example, a dining facility may contribute about 25 percent of its actual electrical load to the peak load of the system.

Step 6. Compute the power factor. You must determine the power factor of an anticipated load before you can accurately estimate the amount of power required for an area. All AC power estimates are calculated using equipment power-factor ratings whenever possible. Noninductive loads such as lights, heaters, and soldering irons are computed at a power factor of 1.0. Inductive loads such as partially loaded transformers and induction motors produce a power factor less than 1.0 because they introduce inductive reactance. The sum of the inductive and noninductive loads is the connected load for the entire installation. The power factor of an AC circuit is the ratio of the true power (watts) to the apparent power (volt-amperes), as shown in the following formula:

$$\textit{Power factor} = \frac{\textit{watts}}{\textit{volt-amperes}}$$

The power (in watts) delivered by a DC generator set is the product of the current multiplied by the voltage. There is no inductive reactance in a DC circuit regardless of the character of the load.

Step 7. Compute the voltage drop. The voltage drop, sometimes called the *line loss*, is the difference between the amount of voltage at the input and output ends of a transmission line and is caused by the resistance of the line. A voltage drop is expressed either as a percentage of the voltage required at the receiving end or as a percentage of the voltage applied by the generator to the line.

The example in *Figure 8-9* shows a generated voltage of 231, a receiving end voltage of 220, and a voltage drop of 11. The voltage drop expressed as a percentage of the voltage at the receiving end is 11/220 or 5 percent. The voltage drop expressed as a percentage of the voltage from the generator end is 11/231 or 4.8 percent of the sending end voltage. The voltage drop is usually shown as a percentage of the voltage required at the receiving end.

The maximum allowable voltage drop for lighting and power loads is 5 percent. This allows no more than a 3 percent loss in the branch lines and no more than a 2 percent loss in the main and feeder lines.

To increase the voltage at the receiving end of the distribution system, increase the voltage output from the generator set. However, the output should never exceed the voltage rating of the generator set. Operators must periodically monitor the voltage throughout the distribution system to identify and correct malfunctions in electrical equipment that is connected to the lines.

A calculated voltage drop is used to plan a distribution system. A system that does not produce enough voltage may cause unexpected results. For example, the heat produced by resistive heating equipment varies as the voltage varies. Thus, a system operating at 10 percent below the rated voltage will produce 19 percent less heat. The heat loss is absorbed by the conductors supplying the power and may cause conductor failure.

Step 8. Allow for growth. Expect the power demands on an electrical circuit to increase in the future. Allow a growth of at least 50 percent of the initial load. When installing a wiring system for electrical power, ensure that the circuit can accommodate at least 50 percent more than the actual connected loads.

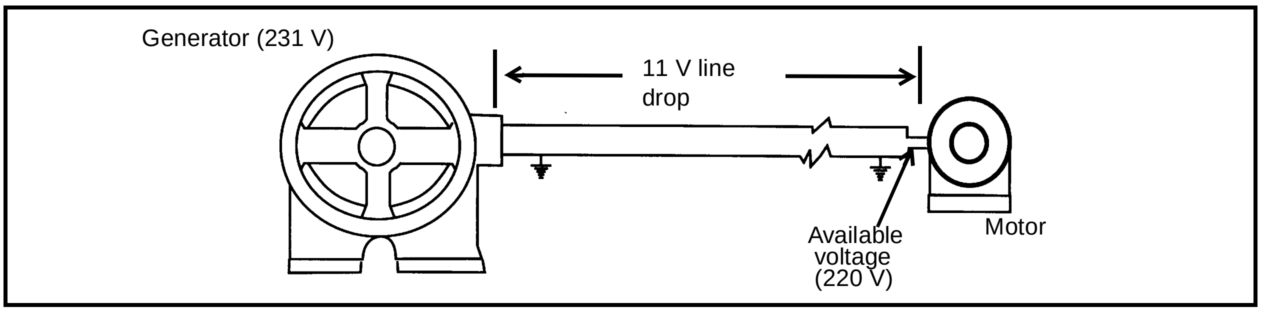

Figure 8-9. Typical line voltage drop

COMPUTING THE CABLE SIZE

A cable connects the generator set to the load. The size of this cable affects the efficiency of the generator. Power losses will occur along the transmission line if the cable is too small. The load current carried by the cable and the distance between the generator set and the load are used to determine the correct cable size.

When a conductor is too small in diameter to carry the current demanded, the cable may overheat and cause the insulation to burn. If the cable wires melt, the circuit will break. The amount of resistance to current flow that occurs along the cable is determined by the distance between the generator set and the load.

Complete the following steps in sequence to determine the cable size required:

Step 1. Use *Table 3-1, page 3-2, and Tables 8-4 and 8-5, page 8-12 through 8-14,* to compute the total current demand for each phase.

Step 2. Use *Table 8-6, page 8-15,* to determine the wire size capable of carrying the total current. If the wire size determined is not available, use parallel runs of smaller wires or use the next larger size. Substitute sizes based on the current-carrying capacities of the wires as listed in *Table 8-7, page 8-16*. The wire substitutions should not produce excessive voltage drops along the distribution line; however, operators must monitor the voltage at the receiving end to ensure that the substituted wire carries the current efficiently.

Table 8-4. Load conversion factors

To Find	Direct Current	Alternating Current	
		Single-Phase	Three-Phase
Amperes when horsepower is known	$\frac{HP \times 746}{E \times Eff}$	$\frac{HP \times 746}{E \times Eff \times PF}$	$\frac{HP \times 746}{1.73 \times E \times Eff \times PF}$
Amperes when kilowatts are known	$\frac{kW \times 1,000}{E}$	$\frac{kW \times 1,000}{E \times PF}$	$\frac{kW \times 1,000}{1.73 \times E \times PF}$
Amperes when kilovolt-amperes are known		$\frac{kVA \times 1,000}{E}$	$\frac{kVA \times 1,000}{1.73 \times E}$
Kilowatts when amperes are known	$\frac{I \times E}{1,000}$	$\frac{I \times E \times PF}{1,000}$	$\frac{I \times E \times 1.73 \times PF}{1,000}$
Kilowatts when horsepower is known	$\frac{HP \times 746}{1,000 \times Eff}$	$\frac{HP \times 746}{1,000 \times Eff}$	$\frac{HP \times 746}{1,000 \times Eff}$
Kilovolt-amperes when amperes are known		$\frac{I \times E}{1,000}$	$\frac{I \times E \times 1.73}{1,000}$
Kilovolt-amperes when horsepower is known		$\frac{HP \times 746}{1,000 \times Eff \times PF}$	$\frac{HP \times 746}{1,000 \times Eff \times PF}$
Horsepower output when amperes are known	$\frac{I \times E \times Eff}{746}$	$\frac{I \times E \times Eff \times PF}{746}$	$\frac{I \times E \times 1.73 \times Eff \times PF}{746}$
Load power factor when rated horsepower and kilovolt-amperes are known		$\frac{HP \times 746}{100 \times kVA \times Eff}$	$\frac{HP \times 746}{100 \times kVA \times Eff}$

I = amperes; E = volts; Eff = efficiency (as a decimal); PF = power factor (as a decimal); kW = kilowatts; kVA = kilovolt-amperes; HP = horsepower.

NOTE: Three-phase, AC lines are assumed to be feeding balanced, three-phase loads. For three-phase loads, input current is per phase.

Step 3. Use *Table 8-8, page 8-17,* to determine the total resistance of the cable when it is connected between the generator set and the load. Ampacity affects the size of wire required for a distribution cable. Ampacity is the current-carrying capacity of a cable or wire expressed in amperes. If the ampacity load is great and the wire length from the generator set to the load is short, ampacity considerations will require a larger wire size than that normally required. When power requirements are low and the length of the line is long, the voltage-drop criteria will require a larger wire size than that normally required. The criteria resulting in the larger size wire governs the design of the distribution system.

NOTE: When installing a cable overhead, use a minimum size of No 8 AWG. An overhead cable must meet the voltage-drop requirement and be strong enough to support its own weight plus any additional weight caused by fallen branches, ice, or snow.

Table 8-5. Full-load currents of motors

HP	120-Volt	240-Volt
1/4	2.9	1.5
1/3	3.6	1.8
1/2	5.2	2.6
3/4	7.4	3.7
1	9.4	4.7
1 1/2	13.2	6.6
2	17	8.5
3	25	12.2
5	40	20
7 1/2	58	29
10	76	38
15		55
20		72
25		89
30		106
40		140
50		173
60		206
75		255
100		341
125		425
150		506
200		675

NOTE: These values of full-load current are average for all speeds and are in accordance with the National Electrical Code.

HP	115-Volt	230-Volt
1/8	4.4	2.2
1/4	5.8	2.9
1/3	7.2	3.6
1/2	9.8	4.9
3/4	13.8	6.9
1	16	8
1 1/2	20	10
2	24	12
3	34	17
5	56	28
7 1/2	80	40
10	100	50

NOTES:

1. These values of full-load current are in accordance with the National Electrical Code and are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

2. For full-load currents of 208- and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

Table 8-6. Table 8-5. Full-load currents of motors (continued)

HP	Induction-Type Squirrel-Cage and Wound Motor Amperes				Sychronous-Type Unity Power-Factor Amperes*				
	110-Volt	220-Volt	440-Volt	550-Volt	2,300-Volt	220-Volt	440-Volt	550-Volt	230-Volt
1/2	4.0	2.0	1.0	0.8					
3/4	5.6	2.8	1.4	1.1					
1	7.0	3.5	1.8	1.4					
1 1/2	10.0	5.0	2.5	2.0					
2	13.0	6.5	3.3	2.6					
3		9.0	4.5	4.0					
5		15.0	7.5	6.0					
7 1/2		22.0	22.0	9.0					
10		27.0	14.0	11.0					
15		40.0	20.0	16.0					
20		52.0	26.0	21.0					
25		64.0	32.0	26.0	7.0	54.0	27.0	22.0	5.4
30		78.0	39.0	31.0	8.5	65.0	33.0	26.0	6.5
40		104.0	52.0	41.0	10.5	86.0	43.0	35.0	8.0
50		125.0	63.0	50.0	13.0	108.0	54.0	44.0	10.0
60		150.0	75.0	60.0	16.0	128.0	64.0	51.0	12.0
75		185.0	93.0	74.0	19.0	161.0	81.0	65.0	15.0
100		246.0	123.0	98.0	25.0	211.0	106.0	85.0	20.0
125		310.0	155.0	124.0	31.0	264.0	132.0	106.0	25.0
150		360.0	180.0	144.0	37.0		158.0	127.0	30.0
200		480.0	240.0	192.0	48.0		210.0	168.0	40.0

*For 90 and 80 percent power factor, the above figures should be multiplied by 1.1 and 1.25, respectively.

NOTES:

1. These values of full-load current are in accordance with the National Electrical Code and are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, in which case the nameplate current rating should be used.

2. For full-load currents of 208- and 200-volt motors, increase the corresponding 230-volt motor full-load current by 10 and 15 percent, respectively.

Table 8-7. Allowable current capacities of conductors, in amperes, for not more than three conductors in a raceway or cable

A	B[1]	C	D	E	F	G
AWG	Rubber Types R, RW, RU, RUW (14-2) Type RH-RW[2] Thermoplastic Types T, TW	Rubber Types RH, RH-RW[2], RHW	Paper Thermoplastic asbestos Type TA Var-Cam Type V Asbestos Var-Cam Type AVB MI Cable	Asbestos varnished-cambric Types AVA, AVL	Impregnated asbestos Types AI (14-8), AIA	Asbestos Types A (14-8), AA
14	15	15	25	30	30	30
12	20	20	30	35	40	40
10	30	30	40	45	50	55
8	40	45	50	60	65	70
6	55	65	70	80	85	95
4	70	85	90	105	115	120
3	80	100	105	120	130	145
2	95	115	120	135	145	165
1	110	130	140	160	170	190
1/0	125	150	155	190	200	225
2/0	145	175	185	215	230	250
3/0	165	200	210	245	265	285
4/0	195	230	235	275	310	340

[1]Insulation type and description.

[2]If type RH-RW rubber-insulated wire is used in wet locations, the allowable current-carrying capacities will be that of column C; and if used in dry locations, the current-carrying capacities will be that of column D.

Type	Description
R	Code-grade rubber compound
RW	Moisture-resistant rubber compound
RU	Latex-rubber compound
RUW	Latex-rubber, moisture-resistant compound
RH-RW	Heat- and moisture-resistant rubber compound
RH	Heat-resistant rubber compound
RHW	Heat- and moisture-resistant compound
T	Thermoplastic-covered for dry locations
TA	Thermoplastic- and asbestos-covered for switchboard wiring
TW	Thermoplastic-covered for moist locations
MI	Mineral-insulated, copper-sheathed for general use and special high-temperature locations
A	Nonimpregnated, all-asbestos, without asbestos outer braid
AA	Nonimpregnated, all-asbestos, with asbestos outer braid
AI	Impregnated, all-asbestos, without asbestos outer braid
AIA	Impregnated, all-asbestos, with asbestos outer braid
AVA	Impregnated-asbestos and varnished-cambric with asbestos braid
AVB	Impregnated-asbestos and varnished-cambric, flame-resistant cotton braid
AVL	Impregnated-asbestos and varnished-cambric, outer asbestos braid, lead-sheathed
V	Varnished-cambric

Table 8-8. Substitute wire sizes

AWG or MCM	Current Carrying Capacity (Amps)	Number and Size of Wires That can be Substituted for a Single Wire of the Size Shown in the First Column				
		2	3	4	5	6
1,000,000	455	300,000	3/0	1/0	2	3
900,000	435	300,000	2/0	1	2	3
800,000	410	250,000	2/0	1	2	4
750,000	400	250,000	2/0	1	3	4
700,000	385	4/0	2/0	1	3	4
600,000	355	4/0	1/0	2	3	4
500,000	320	3/0	1	3	4	6
400,000	280	2/0	2	4	-	6
300,000	240	1/0	3	4	6	8
250,000	215	1	3	6	-	8
4/0	195	1	-	6	8	-
3/0	165	2	6	-	8	10
2/0	145	3	6	8	10	-
1/0	125	4	6	8	10	-
1	110	6	8	10	-	12
2	95	6	8	10	12	-
3	80	8	10	12	-	14
4	70	8	10	12	14	-
6	55	10	12	14	-	-
8	40	12	14	-	-	-
10	30	14	-	-	-	-

BALANCING THE LOAD

The final task before selecting generator sets for a field unit is to balance the load among the phases. When balancing a load, ensure that each phase carries an equal share of the load.

Loads may be connected between a power-carrying conductor (live wire) and a ground wire or between several live wires. When you connect a load between a live wire and a ground wire, any unbalanced current (power) in the line conductors is supplied through the ground wire. A load connected between two or more live wires is distributed equally among the live wires.

An installation fed by a three-phase, four-wire generator set can have a single-phase load attached to each of the three phases. Regardless of the number of loads supplied or how the loads are arranged, the generator supplies the total load on each phase. The generator attempts to supply the power required to satisfy the load in each phase. To ensure that the power is balanced, connect the loads so that each phase receives an equal load of current from the generator set. An unbalanced load has two adverse effects:

- Unbalancing causes high voltage on the lightly loaded phase and low voltage on the other phase(s). This causes poor voltage regulation throughout the system.
- A load that is unbalanced for a long time damages the generating equipment.

Table 8-9. Physical and electrical properties of conductors

Standard Rubber Conductor		IPCEA Class B Stranding	At 77°F (25°C)	
AWG	Circular Mils	No of Wires	Bare Copper	Tinned Copper
18	1,624	7	6.64	7.05
16	2,583	7	4.18	4.43
14	4,107	7	2.63	2.69
12	6,530	7	1.65	1.72
10	10,380	7	1.04	1.08
9	13,090	7	0.824	0.856
8	16,510	7	0.654	0.679
7	20,820	7	0.519	0.538
6	26,250	7	0.410	0.427
5	33,100	7	0.326	0.339
4	41,740	7	0.259	0.269
3	52,640	7	0.205	0.213
2	66,370	7	0.162	0.169
1	83,690	19	0.129	0.134
1/0	105,500	19	0.102	0.106
2/0	133,100	19	0.0811	0.0842
3/0	167,800	19	0.0642	0.0668
4/0	211,600	19	0.0509	0.0525

SINGLE-PHASE SYSTEMS

A single-phase, two-wire, 120-volt system (*Figure 8-10*) cannot be unbalanced because the two wires are connected to one load. When you connect this basic load-carrying circuit, half of the total load is supplied by one live wire while the other live wire supplies the other half of the load.

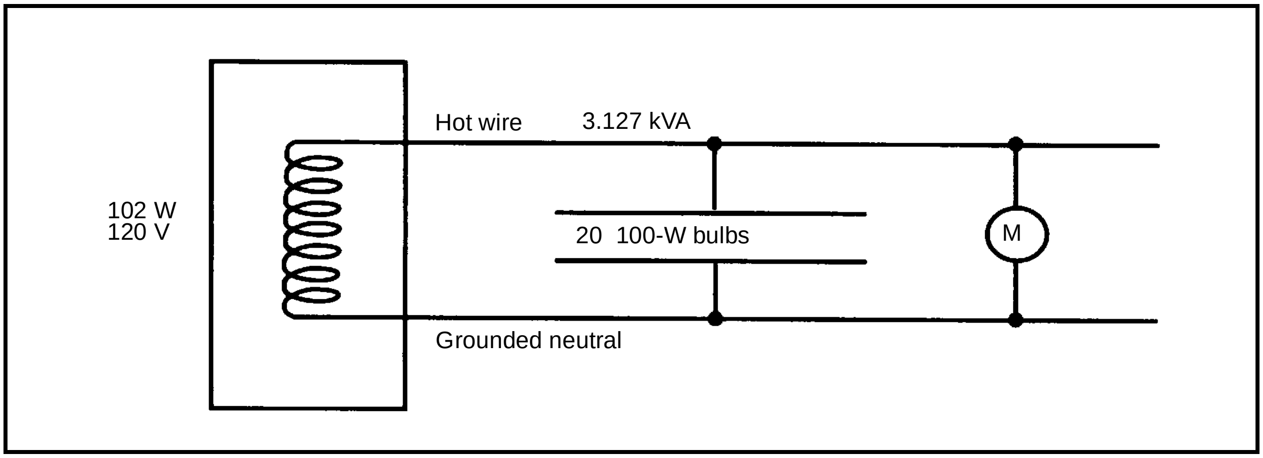

Figure 8-10. Balanced single-phase, two-wire system

A single-phase, three-wire, 120/240-volt system (*Figure 8-11*) has two live wires and one ground wire. It can supply power for two single-phase, 120-volt loads and one single-phase, 208/220-volt load group.

THREE-PHASE SYSTEMS

A three-phase, three-wire, 208-volt system (*Figure 8-12*) has three live wires. It can supply three single-phase, 208-volt loads or one three-phase, 208-volt load. For a single-phase connection, divide the total load equally between the three live wires.

A three-phase, four-wire, 120/208-volt system (*Figure 8-13)* has three live wires and one ground wire. This system can supply power for a single-phase, 120-volt load; a three-phase, 208-volt load; and a single-phase, 208-volt load.

When the total load is balanced, mark on a site diagram the voltage and the number of phases needed. The voltage and phase requirements are marked plainly on most AC and DC motors.

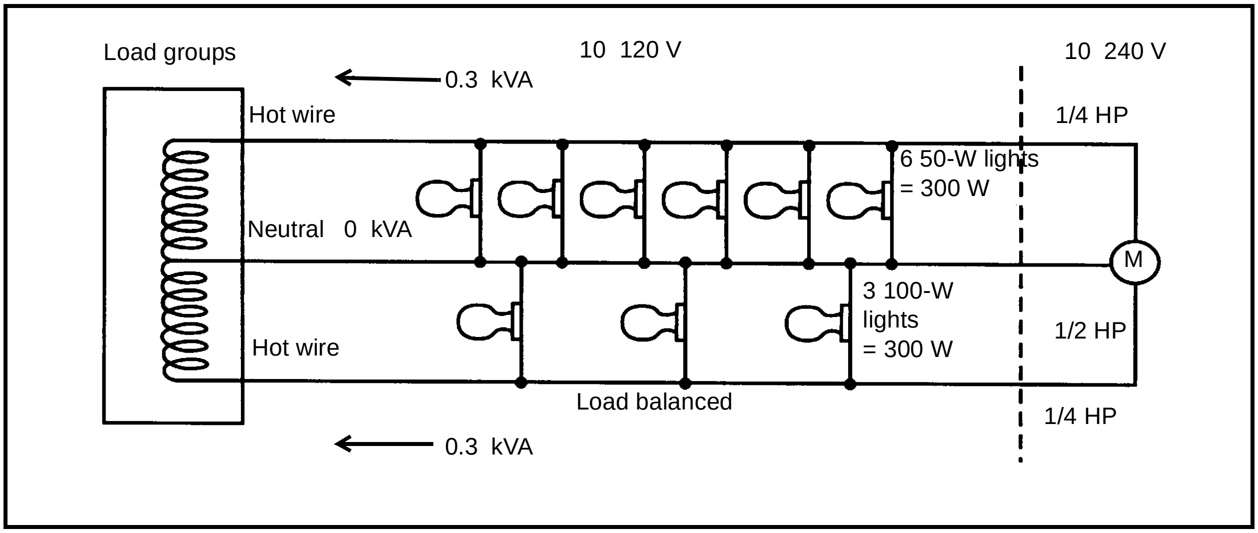

Figure 8-11. Balanced single-phase, three-wire system

SELECTING THE GENERATOR

After you have designed the distribution system and balanced the load, you can select the generating equipment to produce the power needed for the field unit. The electrical systems at most military field units supply power day and night for various lighting, heating, and power equipment. The annual load factor of a well-operated, active field unit is 50 percent or more of the capacity of the generator sets. The annual load has a power factor of 80 percent or more of the average power factor. The following criteria govern the generator selection process:

- Electrical loads to be supplied.
- Kilowatt rating requirements.
- Operating voltages required.
- Number of phases required.
- Frequency requirements.

Other considerations when selecting generating equipment for a field unit include—

- Availability of fuels.
- Expected life of the field unit.
- Availability of skilled maintenance personnel.
- Probable load deviation.

The layout of the field unit is also an important consideration when selecting generating equipment. For example, if the load is more than a few hundred feet from the generator set, you may need a high-voltage distribution system. If the power plant serves a primary distribution system, the generator set must be rated at the distribution system's voltage. This eliminates the need for a transformer at the sending end. Also, the number of phases required by the load may differ from that of the generators on hand. Because most loads can be divided and balanced between phases, most medium- and large-sized generator sets are designed for three-phase operation.

Most electrical loads in the US require a frequency of 60 cycles. Although equipment operators try to maintain a constant frequency throughout the electrical system, deviations sometimes occur. Most electrical equipment operates satisfactorily when the frequency drifts approximately 5 cycles above or below 60 cycles. Some types of equipment, such as teletypewriters and clocks, are sensitive to frequency changes. Consider frequency drift when selecting generator sets that supply power to sensitive equipment.

You must select generator sets that are the proper size and type for the field unit's needs. If a central generating station is needed but there is not enough time to build one, install a generator set at each work site that requires power. The size of the generator set selected for each work site depends on the needs of the site. For example, the electrical load at a headquarters building that consists of lights and single-phase motors can be supplied by a small, single-phase generator set. A maintenance shop that uses large amounts of single-phase and

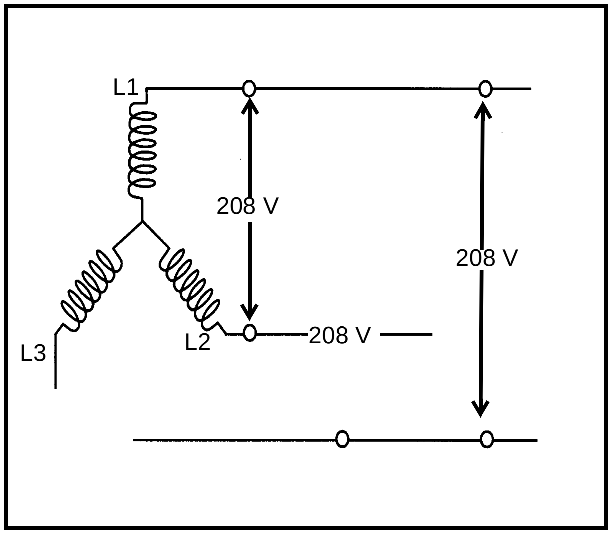

Figure 8-12. Balanced three-phase, three-wire system

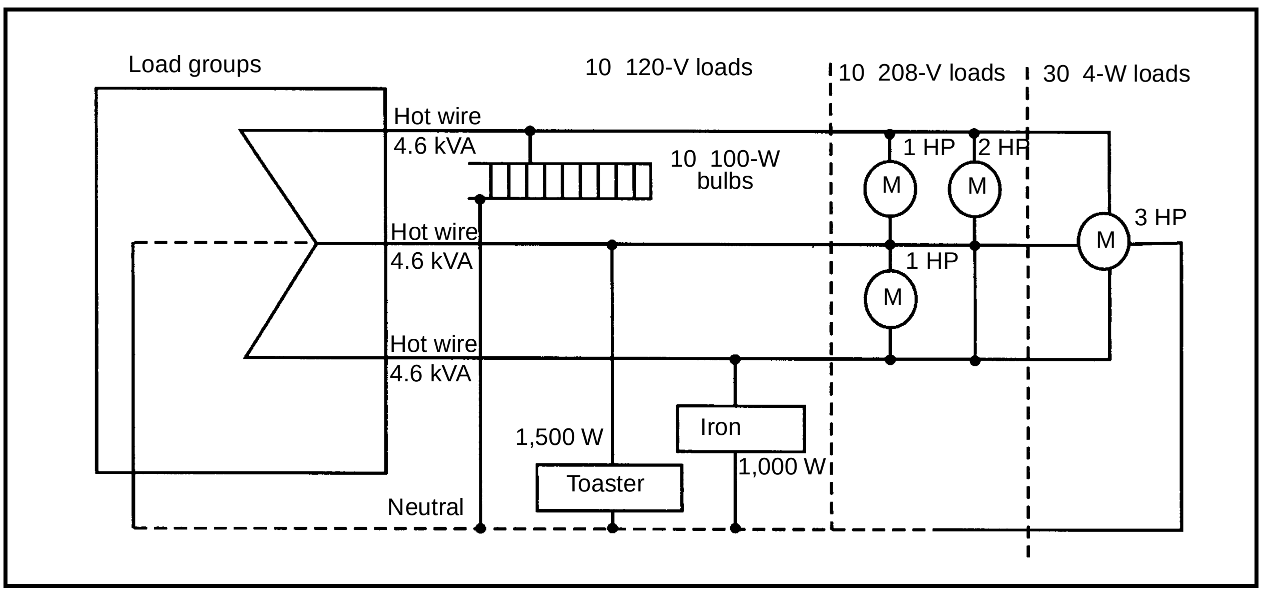

Figure 8-13. Balanced three-phase, four-wire system

three-phase power requires a three-phase generator set.

Coordinate your choice of generator set with the maintenance and supply facilities at the field unit. Maintenance skills and the necessary tools and spare parts required for the selected generator must be available at the field unit.

POWER AND VOLTAGE REQUIREMENTS

The power and voltage requirements of the load determine the size of the generator set used. For example, a two-wire, 120-volt generator set with an output rating of 1.5 kilowatts produces enough electricity for equipment rated at 120 volts, single-phase, with a combined power load of less than 1.5 kilowatts. A 5-kilowatt, AC generator set produces enough electricity for equipment requiring between 1.5 and 4.5 kilowatts.

If motors are part of the load, increase the capacity of the generator set above the capacity normally required. The increased capacity is required to compensate for reduced terminal voltage when large motors are started and when frequency surges occur during motor acceleration. These power drains may adversely affect the performance of electronic systems and other equipment fed from the same generator set. Also, motors already running may stall when large motors are started. You can avoid these and similar problems by removing the existing load when starting a large motor and then placing the small loads back on the generator set after the large motor has reached its required speed.

Some single-phase loads contain equipment rated at both 115 and 230 volts. These loads require a generator set with a single-phase, three-wire, 120/240-volt output.

The size of the load is a primary consideration when selecting a generator set. Determine the capacity needed to support the load before selecting a generator set. Sets with capacities ranging from 0.5 to 500 kilowatts are available.

SELECTION GUIDES

Use the following guides to select a generator set:

- Single-phase equipment provides power for small lighting, AC and DC motors, special equipment such as radial (arc) electrical welders, and some furnace loads. You may use a two- or three-wire system, depending on the size of the load and the area serviced.
- Three-phase equipment provides power for almost everything except small loads. The generation and transmission lines are usually three-wire systems, but the distribution circuits may be three- or four-wire. When single-phase power is obtained from three-phase circuits, operators must balance each phase at the generator set.
- To determine the voltage required for a generator set, consider the distribution circuits; the size, character, and distribution of the load; the length, capacity, and type of transmission lines; and the size, location, and connection of the generator sets.
- Lighting is universally rated at 120 volts in the US. The voltage required for lighting can be obtained from a single-phase, two-wire, 120/240-volt circuit or a three-phase, four-wire, 120/208-volt circuit. Using both lighting and small-motor circuits increases the load requirements for general power applications.
- Small motors (less than 5 horsepower [HP]) are supplied by DC or single-phase AC systems at 120 volts. Large three-phase motors (5 HP or more) usually operate satisfactorily between 200 and 240 volts.
- DC generator sets are used for specific tasks, and selection is based on the task to be performed. Battery charging is the main use of DC generators. A practical wiring diagram of a two-wire, DC generator set is shown in *Figure 8-14*.

- A single generator set is the least desirable method for obtaining continuous electricity. This set is used when it is isolated from the distribution system and when equipment failure will not seriously affect the field unit's mission. A single generator set is sometimes used to power extremely large loads that cannot be tied into a limited distribution system.

Generator sets have gasoline or diesel engines. Consider fuel availability when selecting a generator set because it may limit the choice of engines in advanced or isolated areas. Use the following guides to select the type of engine for a generator set:

- Most gasoline-engine generator sets are similar to small automotive engines. Therefore, maintenance problems on these sets may be easier to correct than maintenance problems on other, less-common engines.
- Diesel-engine generator sets usually operate for longer periods and under greater strains than the gasoline-engine generator sets. Also, diesel engines usually require less maintenance than gasoline engines because of their construction and lack of an ignition system.

LOAD CLASSIFICATION REQUIREMENTS

You must properly match the load to the generator set at the field unit. Loads are classified as *inductive* or *resistive*. The load classification partly determines the amount of load a generator can support. The rating information is in amperes, kilovolt-amperes,

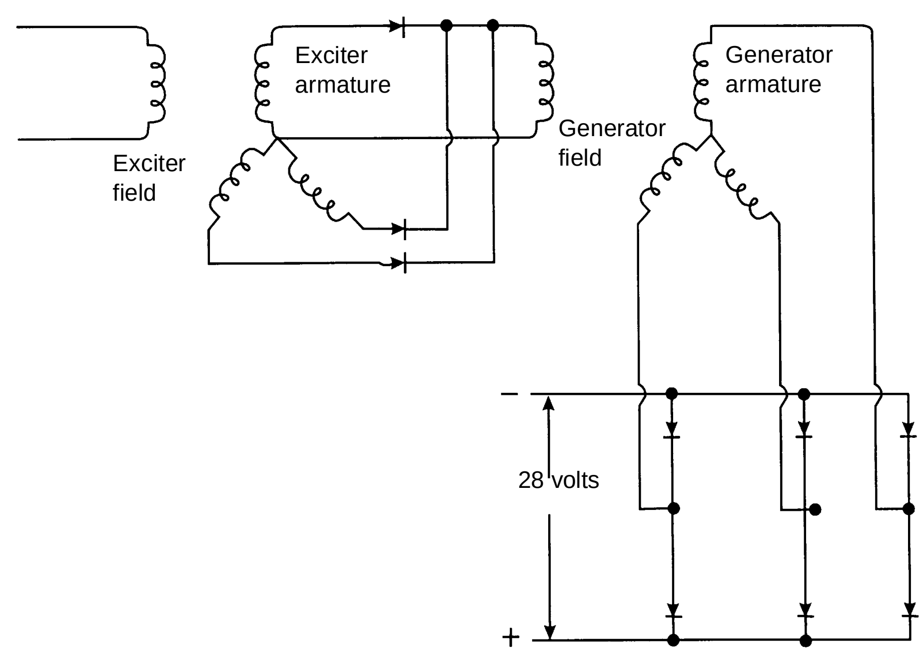

Figure 8-14. Typical wiring diagram of a two-wire, DC generator set

kilowatts, and/or power factors. If the only information you know about a generator set is the kilovolt-amperes, power factor, and voltage-output rating, you must determine the load classification.

A generator can support its kilovolt-amperes rating if the major portion of a load is inductive. For example, a model MEP-017A generator set rated at 6.25 kilovolt-amperes can support a 6.25-kilovolt-ampere inductive load. A generator with a load that is entirely resistive may be overloaded easily because it can support only 80 percent of its kilovolt-ampere rating. For example, a model MEP-017A generator set rated at 6.25 kilovolt-amperes can support only a 5-kilowatt load (6.25 x 0.80 = 5). A generator set with a rating of 0.8 power factor cannot support that rating in kilovolt-amperes if the load is purely resistive (a power factor of 1.0). If the ampere rating is known, calculate the total amperes required to support the load but do not exceed the rating of the generator set.

Many generator sets are designed so that you can select one of several voltages. The ampere rating changes as the voltage output changes. Thus, a model MEP-018A, 5-kilowatt generator set can supply any of the voltages and amperes in *Table 8-9*.

Rating information is on the alternator data plate and in the tabulated data section of the TM for each generator set.

Table 8-10. Voltage and ampere output

Phase	Voltage	Amperes
Single	120	104
Single	240	52
Three	120	34.7 (per phase)
Three	208	17.3 (per phase)

PARALLELING THE GENERATOR SETS

Sometimes a field unit with only small- and medium-sized generator sets needs a large quantity of power. This can be done by connecting and operating two or more generator sets in parallel. When generator sets are connected in this manner, their combined kilowatt rating is equal to the sum of the kilowatt rating for each set. Parallel-connected generator sets are shown in *Figure 8-15*.

Generator sets are connected in parallel to provide continuous power and to allow shutdown time for servicing the equipment. Installations that require continuous power, such as surgical hospitals, use parallel-connected generator sets to avoid power outages. Generator sets are shut down and serviced periodically. When they are connected in parallel, one set can be shut down and serviced while the others continue to operate. Thus, an installation can receive continuous power with no time lost for maintenance and repair.

You must synchronize the parallel generator sets before connecting them to the load. Complete the following steps in sequence to synchronize a base set and an incoming set:

Step 1. Close the main circuit breaker on the base set.

Step 2. Ensure that the voltmeter indicates the frequency required for the load.

NOTE: During the synchronizing process, the base (operating) generator set may be connected to the load and operating or it may be disconnected from the load and operating. After steps 1 and 2 are completed, the incoming generator set may be synchronized with the base unit.

Step 3. Open the circuit breaker on the incoming generator set.

Step 4. Ensure that the voltage and frequency outputs of the incoming generator set are the same as those of the base set.

Step 5. Place the paralleling switch on the control panels of the base and incoming generator sets in the ON position. When the

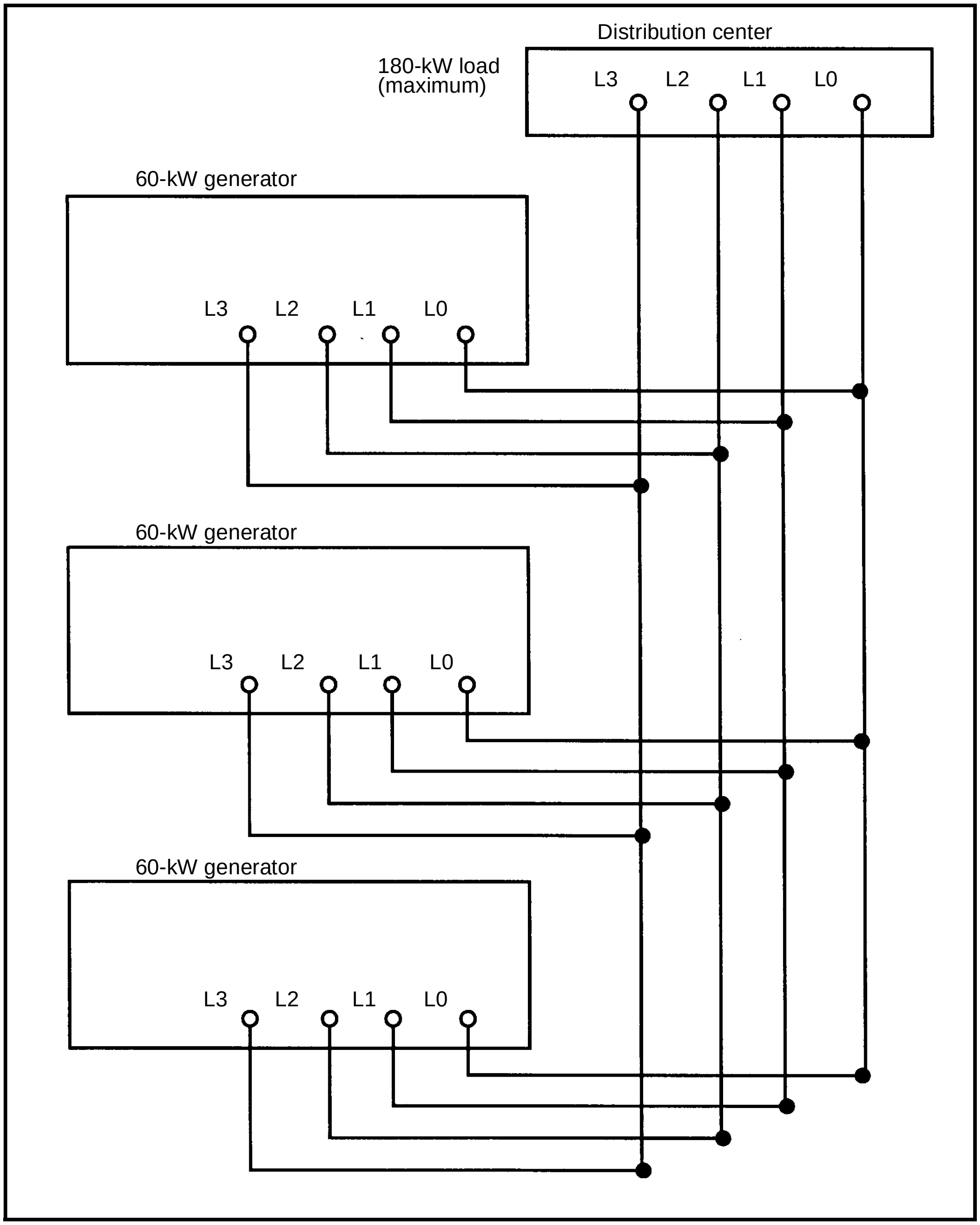

Figure 8-15. Parallel-connected generator sets

paralleling switches are on, the two paralleling lamps on the control panel of the incoming set will begin to blink on and off. Both lights will blink on and off at the same time if the generator sets are connected properly.

NOTE: The following measures should be taken only if the lights do not blink in unison. Turn all power off before reconnecting the generator sets.

Ensure that the lights blink in unison. If the base set is under a power load, observe the kilowatt meter (percent-of-power meter) on the base set. Then go back to the incoming set and observe the paralleling lamps. Adjust the throttle (on utility sets) or the frequency adjust rheostat (on precise sets) until the lamps go on and off at 3- to 5-second intervals. When the lights are completely dark, close the main circuit breaker on the incoming set. Adjust the frequency rheostat of the incoming set until the kilowatt meter indicates one-half of the power of the base set. Adjust the voltage rheostats on both sets, if necessary, to eliminate crosscurrents.

When the synchronizing lamps blink in unison, the two sets are operating in parallel as one base unit.

Step 6. Complete steps 3 through 5 for each additional incoming set. The percent-of-power meter on the third set should indicate one-third of the load on the base set.

CAUTION

If the current meter on either set indicates excessive current and the voltage rheostat will not balance the current, do not operate the generators in parallel. Refer to the next higher level of maintenance.

Step 7. After all generator sets are operating in parallel, divide the load equally among them. To do this, adjust the voltage and frequency outputs of each set. This step completes the paralleling process.

DETERMINING THE GROUNDING SYSTEM

Electrical power-generating equipment must be grounded. In the field, portable power-generating equipment may be grounded with a grounding rod, pipe, or plate. *Figure 3-3, page 3-9,* shows the methods of grounding.

DANGER

If electrical power-generating equipment is not grounded, stray electrical current within the generator set or in the distribution system can injure or kill the operator and damage the equipment.

GROUNDING ROD

The standard grounding rod used by military units is a 5/8-inch copper rod with three 3-foot sections. To install a grounding rod, drive it at least 8 feet into the soil. The rod must be buried below the moisture level. If you cannot do this, replace the grounding rod with an 8-foot electrode. Bury the electrode in a horizontal trench that is at least 2 1/2 feet deep, and place the electrode below the moisture level.

If one grounding rod does not produce a good grounding system, you can form a network with three or more rods. Install the rods about 6 feet apart. If three rods form the network, place them in a straight line or in a triangular pattern. If more than three rods are used, install them in a straight line and connect the grounding cable from the generator set to each grounding rod so they are in series.

GROUNDING PIPE

Use a clean, metallic pipe of 3/4-inch trade size or larger to make a grounding pipe. Pipes made of iron or steel must be galvanized or coated for corrosion protection. Drive the pipe at least 8 feet into the soil. If you cannot do this, replace the pipe with an 8-foot-long electrode. Bury the electrode in a horizontal trench that is at least 2 feet deep and place it below the moisture level.

GROUNDING PLATE

You may use a buried grounding plate (plate electrode) as a ground. The plate must be at least 36 inches wide and 36 inches long (9 square feet). An iron or steel plate may be substituted for a plate electrode if it is at least 1/4-inch thick and coated for corrosion protection. Grounding plates must be buried below the moisture level.

Attach the grounding system with a No 6 AWG or larger cable. Connect one end of the cable to the grounding terminal of the generator set. Tighten the nut securely, as described in the appropriate TM. Connect the other end of the cable to the grounding electrode with a special grounding clamp.

SOIL CONDITIONS

Contact with the earth does not guarantee a good grounding system. The soil type, moisture content, and temperature affect the efficiency of the grounding system. *Table 8-10* describes the characteristics of four types of soils.

Table 8-11. Soil characteristics

Type of Soil	Quality of Ground
Fine soil granules with high moisture content	Very good
Clay, loam, shale	Good
Mixed (clay, loam, shale mixed with gravel or sand)	Poor
Gravel, sand, stone	Very poor

Soil is divided into two distinct layers. Topsoil, the first layer, usually ranges from 1 to 6 inches deep. Because it is often dry and loosely packed, topsoil is not a good electrical conductor. Subsoil, the second layer, is usually tightly packed, retains moisture, and provides the best electrical ground. Wet soil passes electrical current better than dry soil and allows the grounding system to work efficiently.

A chemical solution is used on soils to improve a poor grounding system. To make this solution, mix 5 pounds of sodium chloride (common table salt) with 5 gallons of water (1 pound of salt to 1 gallon of water). Dig a hole that is about 1 foot deep and 3 feet wide. Pour the solution into the hole and allow it to seep into the soil. Install the grounding rod in the hole, connect the grounding strap, and fill the hole with soil. Keep the soil around the rod moist at all times.

Frozen soil is a poor conductor of electrical current. When the soil temperature drops below 32°F and the soil moisture freezes, the effectiveness of the grounding system decreases. To compensate for low soil temperatures, place the grounding system near a source of heat such as a generator set or vehicle exhaust. When it is difficult to install an effective grounding system because the soil is frozen, connect the grounding strap to something that is already grounded, such as a metal building or an underground pipe. If possible, attach the strap with a grounding clamp; if not, attach it with a bolt.

Another alternative is to drive several grounding stakes into the soil at different locations to form a grounding network. Drive the stakes to the greatest depth possible. If necessary, drill, dig, or blast a hole in the soil and use the salt solution described previously. You may also be able to make a temporary ground by driving a spike deep into a large tree.

Geographical locations are important considerations when establishing grounding systems.

- Deserts. The extremely dry and loosely packed desert soils provide a very poor electrical grounding system. Increase the efficiency of the grounding system with the salt solution. Keep the soil around the grounding system moist at all times. Place the equipment near an oasis or subterranean water if possible.
- Mountainous areas. In the rocky terrain typical of mountainous areas, site selection is the key to providing a good grounding system. Try to place the equipment near a streambed.
- Packed, rocky, or frozen soil. Use a slip hammer to drive a grounding rod into this soil. You can make a slip hammer (*Figure 8-16, page 8-26*), or you can order one through normal supply channels.

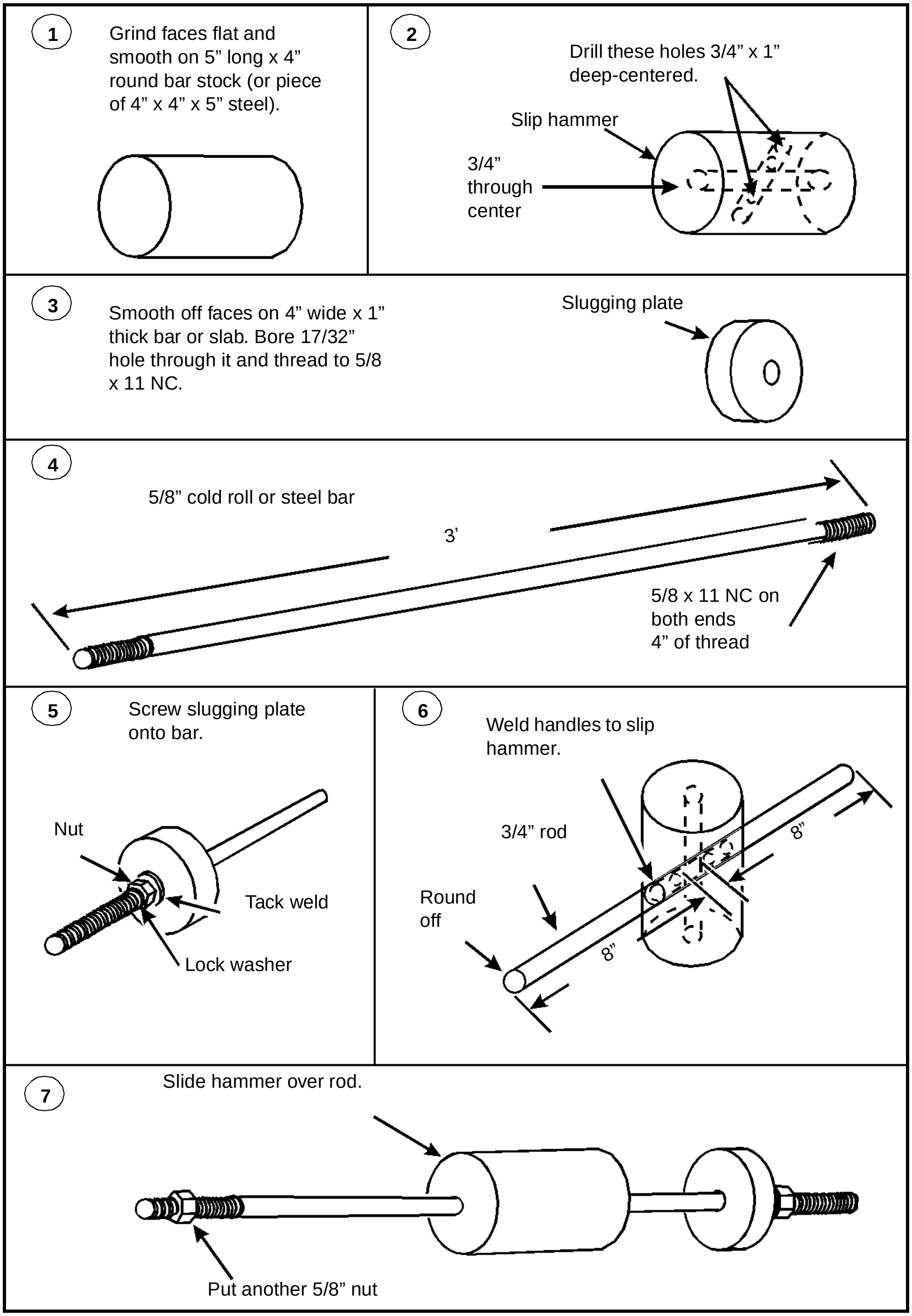

Figure 8-16. Procedures for making a slip hammer

- Tropical areas. Soils in jungles and rain forests provide good electrical ground for the grounding-rod assembly issued with the generator set. You can install grounding rods easily in these moist soils. The fast buildup of corrosion is a problem in the tropics. To ensure a good electrical path, apply waterproof tape at the connection of the grounding strap and keep the grounding rod clean and dry.

Perform the following checks and services to establish a good grounding system:

- Remove paint, oil, and grease from the grounding rods, straps, and connections.
- Keep grounding rods and straps clean.
- Ensure that grounding rods are as straight as possible.
- Keep the points of grounding rods sharp enough to penetrate the soil.
- Ensure that the straps and cable are the proper lengths.
- Use the proper clamps and connections for the grounding system selected.
- Properly tighten the terminal screw and the grounding-clamp screws.

SELECTING THE GENERATOR SITE

The location of the generator set affects the efficiency of the power system. The individual demands for electrical power and the area to be serviced govern the site selected. Generator sets are usually located near the large demands.

You must determine where the large demands are located. To do this, study the map where the individual demands are plotted. If you need additional sets for parallel operations, plot them on the map. All the power demands must be plotted on the map before you select the site and prepare it for the generator set.

Place the generator sets near the largest loads. This practice reduces the size of wire cable required, minimizes the line voltage loss, and provides voltage control at the demand end of the line.

Provide shelter for the generator set. Although the equipment is weather-resistant, it needs protection from inclement weather and enemy fire. A revetment-type shelter provides protection from weather and enemy fire and controls noise levels. Revetment shelters are used for air-cooled generator sets that produce from 0.5 to 10 kilowatts of electricity. The shelter should provide ventilation to maintain a reasonable temperature around the generator and allow heated air and exhaust fumes to escape. If the generator set operates in a closed structure, the exhaust gases must be piped outside.

The pipe used to remove exhaust gases must be installed properly. It should be as short as possible and have no more than one 90-degree bend. Keep combustible materials at lease 6 inches away from the exhaust pipe. Wrap the pipe with insulation if personnel can accidentally touch it.

Use the following guides to select a site for power-generating equipment:

- Provide enough clearance around the generator set to perform maintenance procedures.
- Place the generator set away from areas where noise may be a problem. Most mobile generator sets produce high noise levels.
- Mount the generator set in an area that is clean, level, dry, well-ventilated, and well-drained. Use planks, timbers, logs, ammunition boxes, or other materials to prevent the skids or frame from sinking into soft earth. Keep the set level, preferably within 5 degrees, for proper lubrication. Never tilt the set more than 15 degrees in any direction. You may use cargo trucks for mounting generator sets, but two-wheeled trailers are more common because they offer greater

maneuverability and ease of maintenance. When the set is mounted on a trailer, it is called a *power unit* (*Figure 8-17).*

- Mount the generator set on a surface that can support the weight of the equipment.
- Provide a supply of clean fuel that is sufficient for all requirements planned for the life of the installation. For a long-term installation, consider placing the fuel tanks underground.
- Place the auxiliary fuel tanks for generator sets that produce less than 10 kilowatts as near the shelter as possible. The bottoms of the tanks must be less than 4 feet below the fuel pump on the installed generator set. The fuel tanks for sets producing 15 kilowatts or more must be placed less than 12 feet below the fuel transfer pumps. Connect the fuel line between the auxiliary fuel tank and the fuel selector valve. Ensure that no dirt or moisture gets into the fuel lines.
- Enclose auxiliary fuel supply tanks that are above ground with engineer tape to rope off the area. Place *No Smoking* signs at each entrance to the fuel supply area, at least 50 feet from the fuel supply and the generator set. If possible, construct a shelter to protect the auxiliary fuel supply from rain and direct sun rays. Install a fire point that includes a Class A fire extinguisher, a shovel, and a pickax.

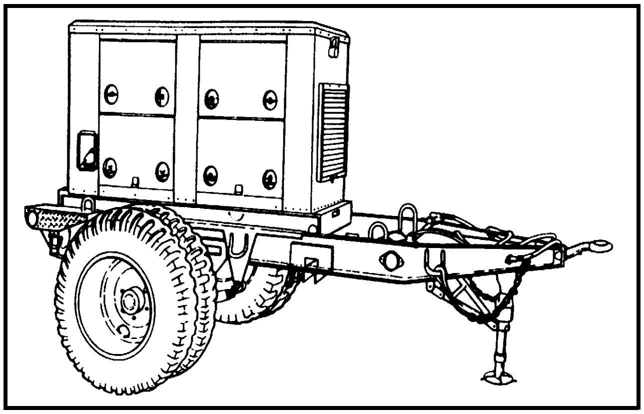

Figure 8-17. Trailer-mounted generator set

- Provide adequate shelter for generators that will be in service at one location for a long period of time. Use noncombustible material for the shelter if possible. Allow a clearance of 4 to 6 feet if you use combustible materials. A lean-to, a shack, or a shed can adequately shelter generating equipment.
- Provide a suitable foundation so the generator set can be bolted to the floor. This will eliminate unnecessary vibrations. Do not use the portable, totally enclosed, and winterized type of generator set in a permanent, indoor installation.

CONSTRUCTING A REVETMENT

Air-cooled, engine-driven generator sets are designed to operate in the open with unrestricted ventilation. However, you may need a revetment (*Figure 8-18*) to protect the equipment from extreme weather and enemy attack. The revetment described in this section is designed to shelter one generator set. Install only one generator set within each revetment. Also, do not place other heat-generating equipment in a revetment with a generator set. Anything that creates heat inside a revetment will adversely affect the cooling of the set.

NOTE: Use revetments only for air-cooled, engine-driven generator sets.

DIMENSIONS

The minimum allowable inside dimensions for a revetment for generator sets rated from 1.5 through 10 kilowatts are 7 1/2 feet long, 5 1/2 feet wide, and 4 feet high. The height includes 1-foot openings around the top of walls that are 3 feet high. The entrance into the revetment should be 2 feet wide. The height of the sill at the bottom of the entrance should be 1 foot or less. A revetment with these dimensions is also suitable for generator sets that produce 0.5 kilowatts of electricity. To economize, however, the width and length can be reduced to 4 feet and 5 feet, respectively.

The above minimum dimensions are based only on engine cooling and ventilation considerations. They allow the minimum space required for servicing and maintaining equipment.

FOUNDATION AND DRAINAGE

Generator sets require an adequate foundation. If the generator set is attached to a shipping pallet, the pallet provides an adequate foundation. If the set is not attached to a pallet, use planks, timbers, logs, ammunition boxes, or other materials to prevent the skids of the frame from sinking into soft earth. The foundation must be less than 6 inches high.

A drainage system is required to ensure that the runoff flows away from the generator set and out of the revetment. Place all drain holes at the inside ground level. Install a sump and drainage trench for each drain hole if the water does not drain away from the revetment naturally. Place a sump and drainage trench outside the revetment.

WALL CONSTRUCTION

The walls of a revetment may be constructed with sandbags, ammunition boxes filled with sand or dirt, or any other materials.

ROOF CONSTRUCTION

The roof can be supported by any means possible, but it must be at least 1 foot above

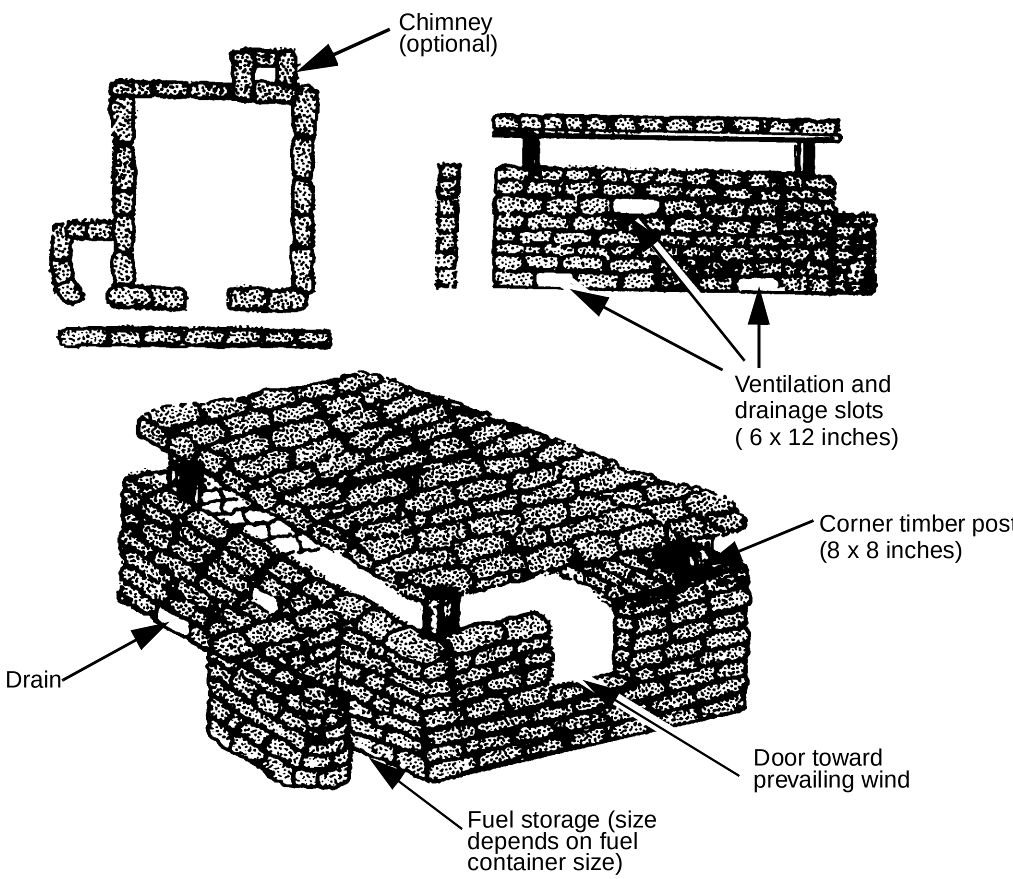

Figure 8-18. Revetment construction

the wall of the revetment. Allow as much open space between the top of the walls and the roof as possible for ventilation. Roof construction usually consists of two pieces of lumber (4 inches by 4 inches) or logs (4 inches in diameter), about 10 feet long, and enough cross pieces of lumber, logs, or steel planking to cover the entire roof. The cross pieces should be about 8 feet long. If the above materials are not readily available, use any available material. The amount and type of protection desired determines the thickness of the roof. When adding roof protection, be sure the roof can support the additional weight. **NOTE: The roof shown in *Figure 8-18, page 8-29,* is covered with sandbags for additional protection.**

> **WARNING**
>
> **Never operate an air-cooled, gasoline-engine generator set inside a closed building unless forced ventilation can remove the engine heat and exhaust gases outside. Exhaust gases contain carbon monoxide, which is a poisonous, odorless, and colorless gas.**

MISCELLANEOUS CONSTRUCTION

Construct a compartment outside the revetment for fuel storage. The size of this storage area depends on the size of the fuel containers. The fuel supply is stored outside the revetment to minimize the hazards associated with fuels at high temperatures. Air temperatures within the revetment increase considerably above the ambient temperature outside when the generator set operates. Some generators are equipped with integral fuel tanks. Do not use the integral fuel tanks in a revetment because of the hazards associated with fuels at high temperatures.

The exhaust from the engine may or may not be ducted out of the revetment. This decision is left to the commander. Install a flexible pipe (chimney) similar to the one shown in *Figure 8-18* if the exhaust is ducted outside. If a flexible pipe is not available, use a piece of exhaust pipe or similar material. The point where the exhaust discharges through the revetment wall depends on the type of generator set and the exhaust pipe. The exhaust may or may not be discharged into an external exhaust chimney. However, a chimney is preferable because it helps duct the exhaust gases away from the revetment and reduces the noise level.

Construct a revetment doorway shield that is similar to a revetment wall. The shield is a wall that prevents projectiles and fragments from entering directly into the revetment. The doorway shield must be 3 feet high and 7 1/2 feet long.

ALIGNMENT INSTRUCTIONS

When constructing a revetment, align the structure so that the door faces into the direction of the prevailing wind. Install the generator set so that its long axis is parallel with the long axis of the revetment. Center the set within the revetment walls. Use the information in *Table 8-11* to orient the generator set.

Table 8-12. Engine-driven generator-set orientation

Generator Set Output (kW)	Orientation
1.5	Generator end toward the door
3.0	Engine end toward the door
4.0	Generator end toward the door
10.0	Generator end toward the door